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G01S 11/06

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(56) Documents Cited
EP 0239156 A EP 0213650 A2 JP 600082876 A
DE 3311349 A

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(54) Abstract Title
Distance measuring apparatus

(57) Apparatus for distance measurement between two locations 1,2 with particular application to mobile communications systems, employs a transmitter at one location 2 and measurement of the cross-correlation between signal received by two orthogonally polarised, co-located antennas 7,8 at the other location 1. The cross-polar-correlation co-efficient dependends on distance (fig 3) from the source 1 in urban environments. This is exploited by the invention.

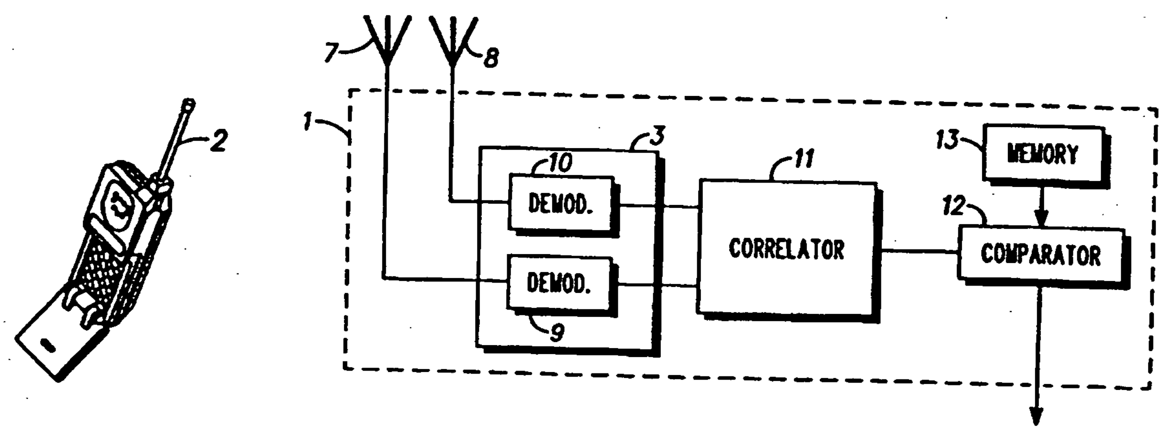

FIG.1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

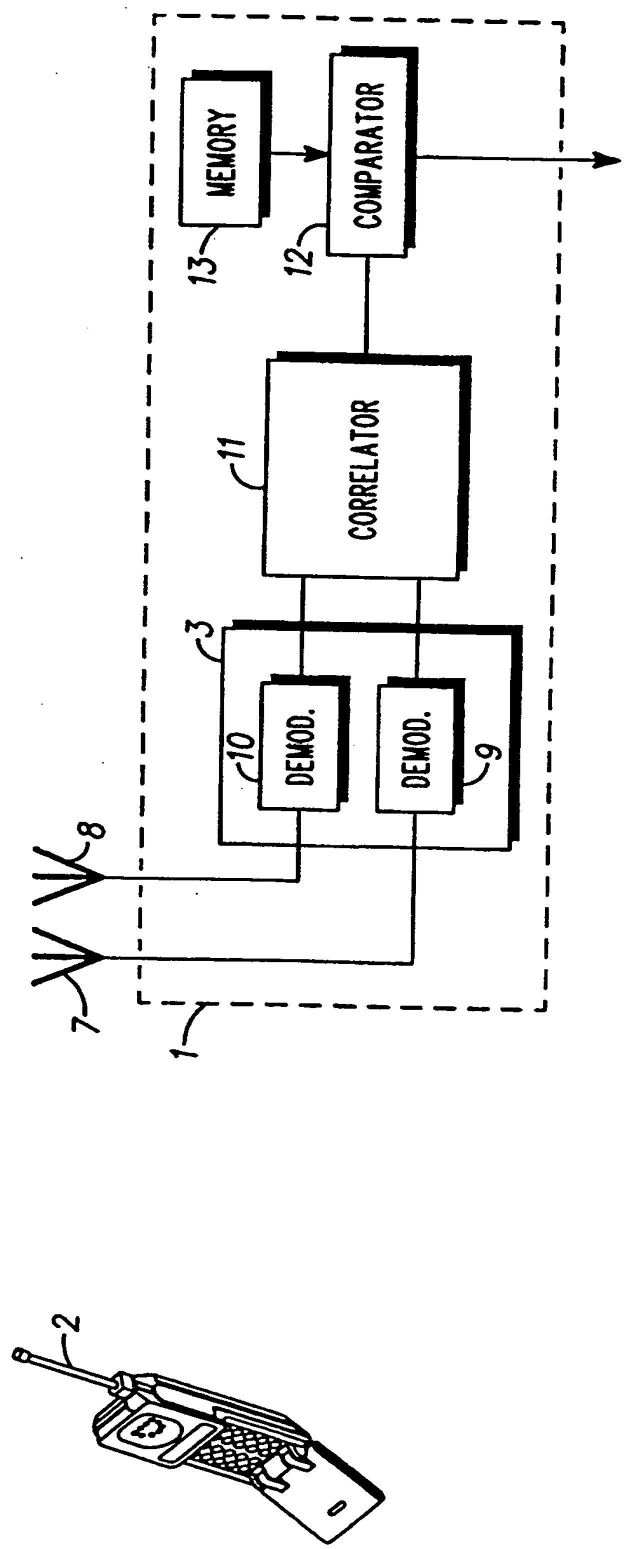
MEMORY
COMPARATOR
CORRELATOR
DEMOD.
DEMOD.
13
12
11
3
10
9
8
7
1
2

FIG.1

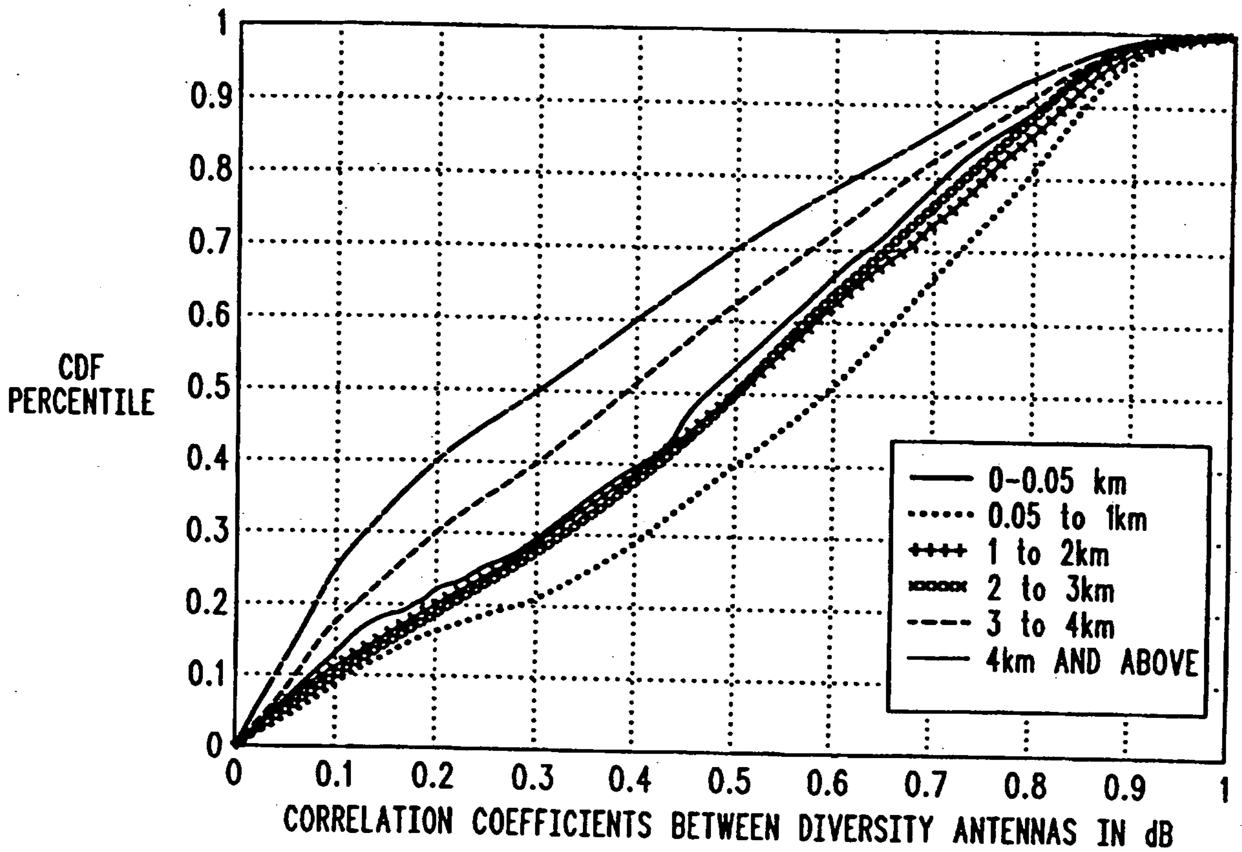
1
0.9
0.8
0.7
0.6
CDF
PERCENTILE
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
CORRELATION COEFFICIENTS BETWEEN DIVERSITY ANTENNAS IN dB
0-0.05 km
0.05 to 1km
1 to 2km
2 to 3km
3 to 4km
4km AND ABOVE

FIG.2

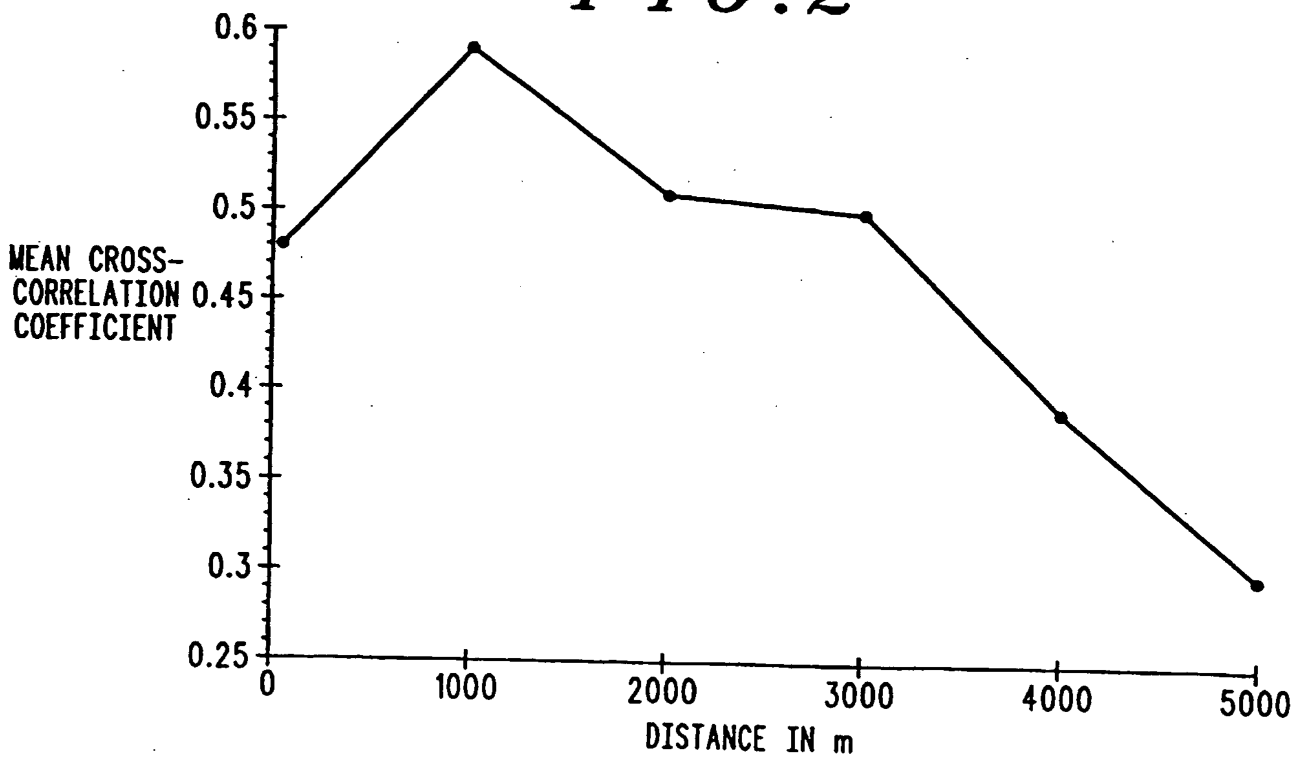
0.6
0.55
0.5
MEAN CROSS-
CORRELATION
COEFFICIENT
0.45
0.4
0.35
0.3
0.25
0
1000
2000
3000
4000
5000
DISTANCE IN m

FIG.3

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DISTANCE MEASURING APPARATUS

This invention relates to distance measurement in radio communication systems and particularly, though not exclusively, to the cellular GSM system (Global System for Mobile Communications), a description of which can be found in the book "The GSM System for Mobile Communications" by M. Mouly and M. Pautet.

Cellular radio telephone systems generally include a switch controller coupled to the public switched telephone network (PSTN) and a plurality of base stations. Each of the plurality of base stations generally defines a geographic region proximate to the base station to produce coverage areas. One or more mobile stations communicate with a base station that facilitates a call between the mobile station and the PSTN. The communication link over a carrier signal from the base station to a mobile station is referred to as the downlink. Conversely, the communication link from a mobile station to the base station is referred to as the uplink.

GSM networks are made up of mobile services switching centres, base station systems and mobile stations. These three entities can be broken down further into smaller entities such as within the base station system there are base station controllers, base transceiver stations and transcoders.

It may be advantageous to determine the location of a mobile station with respect to the fixed base station. For example, such information would be useful to emergency services and to traffic routing services. Most known methods of locating a mobile station in a mobile telecommunications

network involve, amongst other things a calculation of the distance between a base station and in a mobile station. One method of estimating the distance between a base station and a mobile station in a GSM network involves measuring the propagation delay incurred by the carrier signal during its return trip from the base station to a mobile station. (See for example WO-A-9205672).

The radio interface between the base station and the master station in the GSM Network comprises a time division multiple access (TDMA) structure having eight time slots per radio carrier. The TDMA structure is used by channels which are divided into traffic channels and control channels.

The GSM system further contains a function called adaptive frame alignment (AFA). Eight time slots form a TDMA frame. The TDMA frames of all the frequency channels should be aligned with each other. In the base station, the TDMA frame is delayed in the uplink with a fixed period of three time slots from the start of the TDMA frame on the downlink. In the mobile station, the delay in the propagation of the signal is compensated for. This delay is called the timing advance. It is the process of adjusting for this delay which is called adaptive fame alignment (AFA).

Usually, the timing advance TA is measured by the base station each time it detects a transmission on the random access channel RACH. The timing device TA is defined as the delay of the RACH signal relative to an expected signal from a mobile station on the distance. The measured value is rounded to the closest bit period and is signalled to the mobile station. Thus, the value of the timing advance TA may be interpreted as a measure of the distance to the base station. However, the measurement achieved using this known method is not particularly accurate.

This invention provides a method and apparatus for distance measurement which may be used in determining the location of the mobile station and which provides a more accurate estimate of a distance between a base station and a mobile station in a mobile communications network than can be provided by other known systems.

Accordingly, the present invention consists of distance measuring apparatus comprising: a first antenna having an output and being sensitive to receive a first component of an electromagnetic signal, from a remote location, having a first direction of polarisation, a second antenna having an output and being co-located with the first antenna and being sensitive to receive a second component of the electromagnetic signal, from the remote location, having a second direction of polarisation offset from the first direction of polarisation, means for measuring cross-correlation between the antenna outputs and means for comparing the cross-correlation with a pre-determined value related to distance, thereby determining the distance from the antennas to the remote location.

Preferably, cross-correlation is determined over a valid statistical averaging period and compared against the average correlation co-efficients with physical positions of existing collected data. An estimate of the distance between the antenna location and the remote location can then be determined from a simple look-up table.

In cases where the invention is to be incorporated into a GSM cellular radio network, the apparatus can be incorporated either in the base station or in the mobile station.

Some examples of the invention will now be described, by way of example only, with reference to the drawings of which:

FIG. 1 is a schematic block diagram of distance measuring apparatus in accordance with the invention and incorporated into a mobile radio telephone communications system,

FIG. 2 is a graph with several plots at various distances of cumulative probability density function (CDF) percentile versus correlation co-efficient between dual orthogonally polarised antennas, and

FIG. 3 is a graph showing the relationship between a cross-correlation co-efficient and distance derived from Figure 2.

In Figure 1, a base station 1 at a fixed location, communicates with a remote mobile station 2. In accordance with usual practice, the base station 1 includes receiver circuitry 3 and transmitter circuitry 4 both connected via a duplexer 5 to an antenna system 6.

In accordance with the invention, the antenna system 6 comprises two orthogonal polarised antenna elements 7 and 8 which are connected to the receiver 3. The receiver 3 is configured as dual polarisation diversity receiver and includes separate base-band demodulation stages 9 and 10 for each antenna input. The outputs of each stage 9 and 10 are connected to a correlator stage 11. The output from the correlator stage 11 of the receiver 3 is fed to a first input of a comparator 12. A second input of the comparator 12 is connected to a memory 13 which comprises look-up tables relating distance to cross-correlation values.

The inventor has discovered that cross-polarisation discrimination of the signal received at the base station 1 from the mobile station 2 in an urban environment, can be used to determine base station-to-mobile station distance on a statistical basis.

Figure 2 shows the simultaneously measured cross-correlation statistics between the two antenna elements 7 and 8. The effects of distance from

base station 1 to mobile station 2 can be seen, with the lower cross-correlation statistics at distances beyond 3 kilometres. Additionally, there is a parabola effect in the near-in distances. It is clear that this is not a signal-to-noise effect on the received cross-correlation because the same data set taken on spatial antennas shows no such trends.

Taking the average figure for cross-polar-correlation, (ie a CDF percentile value of 0.5) a further graph of cross-correlation coefficient versus distance can be plotted (see figure 3) ie the parabola around the cross-correlation co-efficients can be used to determine distance between base station 1 and mobile station 2.

Returning then to Figure 1, in operation, the base station 1 and mobile station 2 communicate in the usual manner with the additional computation performed at the base station 1 as follows. The signal received from the mobile station 2 is effectively split into two orthogonally polarised channels by the action of the two antennas elements 7 and 8. Cross-correlation been the two channels is performed in the correlator stage 11 (by comparing the intensities of the signals in each channel) and a cross-correlation co-efficient is determined and output therefrom. This coefficient is compared with a look-up table derived from the information contained in Figure 2, for example, which is stored in the memory 13. The comparator 12 thereby outputs a value of base station to mobile station distance.

The distance value computed can, if desired, be used to update, complement or use independently of the timing advance TA simply by dividing the distance value by the speed of light to calculate the return trip time from base station to mobile station.

Further, any ambiguity in the distance determination can be resolved by comparing this computed value for timing advance with the timing

advance value generated in the conventional fashion as is inherent in GSM architectures.

Claims

1. Distance measuring apparatus comprising a first antenna having an output and being sensitive to receive a first component of an electromagnetic signal, from a remote location, having a first direction of polarisation,

a second antenna having an output and being co-located with the first antenna and being sensitive to receive a second component of the electromagnetic signal, from the remote location, having a second direction of polarisation offset from the first direction of polarisation,

means for measuring cross-correlation between the antenna outputs,

and means for comparing the cross-correlation with a predetermined value related to distance, thereby determining the distance from the antennas to the remote location.

2. Distance measuring equipment as claimed in Claim 1 in which the second direction of polarisation is offset from the first direction of polarisation by 90 degrees.

3. Distance measuring apparatus as claimed in Claim 1 or Claim 2 and incorporated in a base station of a mobile telecommunications network.

4. Apparatus as claimed in Claim 1 or Claim 2 and incorporated in a mobile station of a mobile communications network.

5. A method of distance measurement including the steps of:

receiving at a first antenna, a first component of an electromagnetic signal, from a remote location, having a first direction of polarisation,

receiving at a second antenna co-located with the first antenna, a second component of the electromagnetic signal, from the remote location, having a second direction of polarisation offset from the first direction,

cross-correlating the outputs of the antennas, and comparing the resulting cross-correlation with a pre-determined value related to distance, thereby determining distance from the antennas to the remote location.

6. A method as claimed in Claim 5 in which the step of cross-correlating the outputs of the antennas is performed over a pre-determined statistical averaging period.

7. A method of measuring the distance between a mobile station and a base station in a mobile telecommunications network which method comprises the distance measuring method of either of Claims 5 or 6.

8. Distance measuring apparatus substantially as hereinbefore described with reference to the drawings.

9. A method of distance measurement substantially as hereinbefore described with reference to the drawings.

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The Patent Office

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Claims searched:	all	**Date of search:**	15 June 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4D (DD, DLRJ)

Int Cl (Ed.6): G01S

Other: Online: WPI, JAPIO, CLAIMS

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP0239156A	HOLLANDSE	
A	EP0213650A2	NEIDELL	
A	DE3311349A	MBB	
A	JP600082876A	HITACHI	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.